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Waveform analysis of crosshole GPR data collected in heterogeneous chalk deposits

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Chalks are important reservoirs for groundwater production onshore Denmark and for hydrocarbons in the North Sea Basin. Therefore this rock type is studied extensively with geological and geophysical methods. Ground-penetrating radar (GPR) tomography is used to characterize fine-scale reservoir properties, e.g. subtle changes in porosity.

We have conducted a range of high-resolution GPR crosshole experiments in Boesdal quarry in Eastern Denmark. The objective is to investigate the impact of fine-scale heterogeneity on reservoir properties in chalk. The studied chalk interval is c.15 m thick. It can be divided into two main units based on the traveltime analysis and interpretation of the cored material from the boreholes. The lower unit consists mainly of porous calcareous mudstone with occasional occurrences of flint nodules. The upper succession is c. 8 m thick and is fairly heterogeneous with multiple beds of wackestones and packstones with abundant flint nodules or bands. The heterogeneity of the upper layer is expressed by more complex waveforms than the lower unit. Pronounced attenuation of the transmitted wave fields is observed in the highly porous lower unit.

Full-waveform inversion methods are highly dependent on the quality of the starting models (usually obtained from ray-based tomography), as well as on the assumptions made regarding the source signal. Adequate estimation of starting models and source waveform is, however, a challenging task for the strongly heterogeneous chalk material. We highlight the critical aspects regarding these tasks for the two contrasting layers. Furthermore we demonstrate how different starting models and assumptions regarding the source signal estimation affect the waveform inversion results.